CHAPTER 03200 HYDROLOGY

SECTION 03201 BASIC POLICIES AND REQUIREMENTS

The following section provides a list of design policies which must be applied during a hydrologic analysis performed within the City of Westfield jurisdictional area.

03201.01 Abbreviations and Definitions

Following are discussions of concepts which will be important in a hydrologic analysis. These concepts will be used throughout the remainder of this chapter in dealing with different aspects of hydrologic studies.

Abbreviations

COE:	United States Army Corps of Engineers
IDEM:	Indiana Department of Environmental Management
IDNR:	Indiana Department of Natural Resources
INDOT:	Indiana Department of Transportation
NRCS:	USDA-Natural Resources Conservation Service
USDA:	United States Department of Agriculture

Definitions

Antecedent Moisture Condition:	The index of runoff potential before a storm event. The index, developed by the Natural Resource Conservation Service (NRCS), is an attempt to account for the variation of the NRCS runoff curve number (CN) from storm to storm.
Catch Basin:	A chamber usually built at the curb line of a street for the admission of surface water to a storm drain or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.
Channel:	A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.

Culvert:	A closed conduit used for the conveyance of surface drainage water under a roadway, railroad, canal or other impediment.
Curve Number:	The NRCS index that represents the combined hydrologic effect of soil, land use, land cover, hydrologic condition and antecedent runoff condition.
Depression Storage:	Non-riverine depressions in the earth where stormwater collects. The volumes are often referred to in units of acre-feet.
Design Storm:	A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.
Drainage Area:	The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.
Duration:	The time period of a rainfall event.
Hydrograph:	For a given point on a stream, drainage basin, or a lake, a graph showing either the discharge, stage (depth), velocity, or volume of water with respect to time.
Infiltration:	Passage or movement of water into the soil.
Inlet:	An opening into a storm drain system for the entrance of surface storm water runoff, more completely described as a storm drain inlet.
Major Drainage System:	Drainage system carrying runoff from an area of one or more square miles.
Minor Drainage System:	Drainage system carrying runoff from an area of less than one square mile.
Peak Discharge:	The maximum instantaneous flow from a given storm condition at a specific location.
Rainfall Intensity:	The rate at which rain is falling at any given instant, usually expressed in inches per hour.
Runoff:	That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.

Storm Frequency: The time interval between major storms of predetermined intensity and volumes of runoff (e.g. a 5-yr., 10-yr., or 20-yr. storm).

Storm Sewer: A closed conduit for conveying collected storm water, while excluding sewage and industrial wastes. Also called a storm drain.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Time of Concentration: The travel time of a particle of water from the most hydraulically remote point in the contributing area to the point under study. This can be considered the sum of an overland flow time and times of travel in street gutters, storm sewers, drainage channels, and all other drainage ways.

Watercourse: Any river, stream, creek, brook, branch, natural or man-made drainageway in or into which stormwater runoff or floodwaters flow either continuously or intermittently.

Watershed: The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.

Symbol Table: To provide consistency within this chapter as well as throughout this manual the following symbols will be used. These symbols were selected because of their wide use in hydrologic publications. In some cases the same symbol is used in existing publications for more than one definition. Where this occurs in this chapter, the symbol will be defined where it occurs in the text or equations.

Symbols	Definition	Units
A	Drainage Area	acres
C	Runoff Coefficient	-
CN	NRCS-runoff curve number	-
D	Duration	hours
I	Rainfall intensity	in/hr
n	Manning roughness coefficient	-
Q	Rate of runoff	cfs
q_p	Peak rate of discharge	cfs
t_c or T_c	Time of concentration	min
V	Velocity	ft/s

03201.02 Hydrologic Methods

Runoff rates shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under development. The rate of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

A. Development Sites Less than or Equal to 5 Acres in Size, With a Contributing Drainage Area Less than or Equal to 50 Acres and No Depressional Storage

The Rational Method may be used. A computer model, such as TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE), that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies may also be used along with a 24-hour duration NRCS Type 2 storm. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 03700 (Post-Construction Stormwater Quality Management), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 03700 and BMP Fact Sheets may be determined based on pre-development underlying soil layer.

In the Rational Method, the peak rate of runoff, Q, in cubic feet per second (cfs) is computed as:

$$\mathbf{Q = CIA}$$

Where: C = Runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall.

I = Average intensity of rainfall in inches per hour for a duration equal to the time of concentration (t_c) for a selected rainfall frequency.

A = Tributary drainage area in acres.

Values for the runoff coefficient "C" are provided in Table 03201-1, which shows values for different types of surfaces and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types.

Rainfall intensity shall be determined from the rainfall frequency data shown in Table 03201-2.

In general, the time of concentration (t_c) methodology to be used for all stormwater management projects within the City of Westfield jurisdictional area shall be as outlined in the U.S. Department of Agriculture (USDA) - NRCS TR-55 Manual. In urban or developed areas, the methodology to be used shall be the sum of the inlet time and flow time in the stormwater facility from the most remote part of the drainage area to the point under consideration. The flow time in the storm sewers may be estimated by the distance in feet divided by velocity of flow in feet per second. The velocity shall be determined by the Manning's Equation (see Chapter 03300). Inlet time is the combined time required for the runoff to reach the inlet of the storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches, and sheet flow across such areas as lawns, fields, and other graded surfaces.

B. Development Sites Greater Than 5 Acres in Size or Contributing Drainage Area Greater than 50 Acres or With Significant Depressional Storage

The runoff rate for these development sites and contributing drainage areas shall be determined by a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies and the 24-hour NRCS Type 2 Rainfall Distribution. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

> **LID Exception:** If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 03700 (Post-Construction Stormwater Quality Management), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 03700 and BMP Fact Sheets may be determined based on pre-development underlying soil layer.

The 24-hour Rainfall depth for various frequencies shall be taken from Table 03201-3. The NRCS Type 2 distribution ordinates are found in Table 03201-4. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). These programs may be downloaded free of charge from the associated agencies' web sites. The computer models ICPR and Pond Pack may also be used. However, the latter computer software is proprietary. If interconnected ponds are utilized, the use of ICPR or Pond Pack may be required to appropriately model the more complex hydrologic and hydraulic relationships associated with such system. Other models may be acceptable and should be accepted by the WPWD prior to their utilization.

C. Development Sites with Drainage Areas Greater than or Equal to One Square Mile

For the design of any major drainage system, as defined in Section 03201.01, the discharge must be obtained from, or be accepted by, the IDNR. Other portions of the site must use the discharge methodology in the applicable section of this Chapter.

03201.03
Design Storm
Frequencies

The design storm frequency is the basis for all runoff computations and stormwater facility designs. All stormwater facilities, whether private or public, and whether constructed on private or public property, shall conform to the design standards and other requirements contained herein.

1. All storm sewers, inlets, catch basins, and street gutters shall accommodate (subject to the "allowable spread" provisions discussed later in this Section), as a minimum, peak runoff from a 10-year return frequency storm calculated based on methodology described in Section 03201.02. Any upstream, off-site runoff being bypassed through the development's storm sewer system must be accommodated for the 10-year event, with overland flow path provisions considered for bypassing flows in excess of the 100-year event. Additional discharges to storm sewer systems allowed in Section 03501.06 must also be considered in all design calculations. For Rational Method analysis, the duration shall be equal to the time of concentration for the drainage area. In computer based analysis, the duration is as noted in the applicable methodology associated with the computer program.

2. Primary, secondary, and collector street culverts and bridges as noted by the City of Westfield Thoroughfare Plan shall be capable of accommodating, without overtopping the road, peak runoff from a 100-year frequency storm when crossing under a road. All other roadway culverts shall be designed for 50-year frequency storm without overtopping. Bridges that meet the above threshold shall also have a minimum of 2 feet of freeboard below the low chord (lowest structural member) of the bridge structure for the design 100-year flood.

3. For portions of the system considered minor drainage systems, the allowable spread of water on Collector Streets is limited to maintaining two clear 10-foot moving lanes of traffic. One lane is to be maintained on local roads, while other access lanes (such as a subdivision cul-de-sac) can have a water spread equal to one-half of their total width.

4. To ensure access to buildings and allow the use of the roadway by emergency vehicles during storms larger than the design storm, an overflow channel/swale between sag inlets and overflow paths or basin shall be provided at sag inlets so that the maximum depth of water that might be ponded in the street sag shall not exceed 7 inches measured from elevation of gutter.

5. Stormwater facilities functioning as a major drainage system as defined in Section 03201.01 must also meet IDNR design standards in addition to the City of Westfield Public Works Department Standards and Specifications. In case of discrepancy, the most restrictive requirements shall apply.

6. All channels and swales shall accommodate, as a minimum, peak runoff from a 10-year return frequency storm calculated based on methodology described in Section 03201.02. For Rational Method analysis, the storm duration shall be equal to the time of concentration for the drainage area. In computer-based analysis, the duration is as noted in the applicable methodology associated with the computer program.

7. Channels with a carrying capacity of more than 30 cfs at bank-full stage shall be capable of accommodating peak runoff for a 50-year return frequency storm within the drainage easement.

8. The 10-year storm design flow for residential rear and side lot swales shall not exceed 4 cfs. The maximum length of rear and side lot swales before reaching any inlet shall not exceed 3 residential lots or 300 feet, whichever is shorter, unless designed as a stormwater quality BMP that meets the design criteria provided in Chapter 03700.

9. Regardless of minimum design frequencies stated above, the performance of all parts of drainage system shall be checked for the 100-year flow conditions to insure that all buildings are properly located outside the 100-year flood boundary and that flow paths are confined to designated areas with sufficient easement.

TYPE OF SURFACE	RUNOFF COEFFICIENT ©
Non-Urban Areas	
Bare earth	0.55
Steep grassed areas (slope 2:1)	0.60
Turf meadows	0.25
Forested areas	0.20
Cultivated fields	0.30
Urban Areas	
All watertight roof surfaces	0.90
Pavement	0.85
Gravel	0.85
Impervious soils (heavy)	0.55
Impervious soils (with turf)	0.45
Slightly pervious soil	0.25
Slightly pervious soil (with turf)	0.20
Moderately pervious soil	0.15
Moderately pervious soil (with turf)	0.10
Business, Commercial & Industrial	0.85
Apartments & Townhouses	0.70
Schools & Churches	0.55
Single Family Lots < 10,000 SF	0.45
Lots < 12,000 SF	0.45
Lots < 17,000 SF	0.40
Lots > ½ acre	0.35
Park, Cemetery or Unimproved Area	0.30

TABLE 03201-1: Runoff Coefficients © for Use in the Rational Method

Rainfall Intensities for Various Return Periods and Storm Durations							
Duration	*Intensity (Inches/Hour)*						
	Return Period (Years)						
	1	2	5	10	25	50	100
5 min	5.09	6.02	7.14	8.09	9.26	10.26	11.2
10 min	3.95	4.7	5.54	6.24	7.09	7.78	8.42
15 min	3.23	3.83	4.54	5.12	5.84	6.42	6.98
30 min	2.14	2.56	3.11	3.55	4.12	4.59	5.04
1 hr	1.3	1.57	1.95	2.26	2.67	3.02	3.37
2 hr	0.76	0.92	1.15	1.34	1.6	1.82	2.05
3 hr	0.54	0.65	0.81	0.95	1.14	1.3	1.47
6 hr	0.32	0.39	0.48	0.56	0.68	0.78	0.88
12 hr	0.19	0.22	0.28	0.32	0.38	0.43	0.49
24 hr	0.11	0.13	0.16	0.18	0.21	0.23	0.26

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Fishers, Indiana. (Partial Duration series, upper 90% Confidence Interval, values for intermediate durations can be logarithmically interpolated.)

TABLE 03201-2: Rainfall Intensities for Various Return Periods and Storm Durations

Rainfall Depths for Various Return Periods							
Duration	*Depth (Inches)*						
	Return Period (Years)						
	1	2	5	10	25	50	100
24 Hrs.	2.54	3.05	3.75	4.29	5.04	5.62	6.22

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Fishers, Indiana. (Partial Duration series, upper 90% Confidence Interval).

TABLE 03201-3: Rainfall Depths for Various Return Periods

Cumulative Percent of Storm Time	Cumulative Percent of Storm Depth	Cumulative Percent of Storm Time	Cumulative Percent of Storm Depth
0	0	52	73
4	1	53	75
10	2.5	54	77
15	4	55	78
20	6	56	80
25	8	57	81
30	10	58	82
33	12	60	83.5
35	13	63	86
38	15	65	87
40	16.5	67	88
42	19	70	89.5
43	20	72	91
44	21	75	92
45	22	77	93
46	23	80	94
47	26	83	95
48	30	85	96
48.5	34	87	97
48.7	37	90	98
49	50	95	99
50	64	100	100
51	71		

TABLE 03201-4: NRCS Type 2 Rainfall Distribution Ordinates
(for use when not already built in the computer program)